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Preview Control: A Review

Abstract. *The advanced knowledge of reference signal plays a vital role in enhancing the tracking performance of a control system. Disturbance rejection can also be improved if future values of exogenous signals are available. The use of future information (reference and/or disturbance) in the design of control systems is termed as "preview control". In preview control, a controller can look ahead and use information about the command from time t to time t+t_{la} where t_{la} is called the preview length. Preview control is related to a distinct class of control problems with a preview length that spreads for a fixed time into the future. In this paper a review of preview control has been presented.*

Streszczenie. *W artykule przedstawiono przegląd metod sterowania bazującego na informacji o przyszłych wartościach zadanych i zakłóceniach. Metody te pozwalają na „podgląd" przyszłego stanu układu i uwzględnienie tych informacji w algorytmie sterowania. (**Sterowanie z wykorzystaniem podglądu – przegląd metod**).*

Keywords: Preview control, H∞ control, Preview length
Słowa kluczowe: sterowanie H∞, długość podglądu.

Introduction

The use of future information in the design of control systems is termed as look ahead or preview control. In many control systems it is required that the output should track the reference signal in the presence of exogenous signals. The optimal preview controller makes use of future information about reference and/or disturbances to obtain better tracking and/or disturbance rejection [1].

The block diagram representation of an open loop preview control scheme is shown in fig.1.

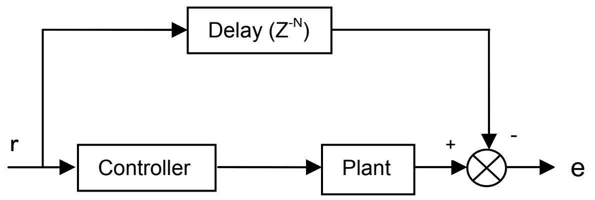

Fig.1. Open loop preview control

Here r is the future value of reference signal which acts as an input to the feed-forward controller. The preview action appears due to delay which can be represented by Z^{-N} which means an N step delay. The future value of the reference signal and the controller are chosen in such a way so as to minimize the tracking error e. If G(z) represents the transfer function of the stable plant then e(z)=G(z)K(z)-Φ(z) where K(z) and Φ(z) are transfer function controller and delay function. If $K(z)=G(z)^{-1}\Phi(z)$ then e(z)=0.

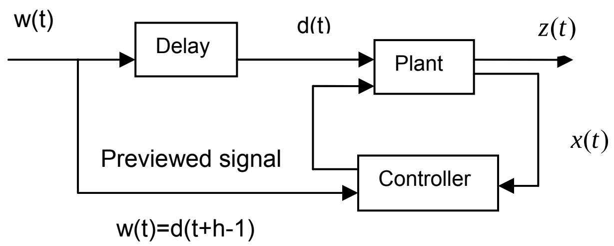

Fig.2. Closed loop preview control scheme[1]

Fig. 2 shows the block diagram representation of closed loop preview control scheme [1]. The previewed signal is represented by w(t)=d(t+h-1) where w(t) is the command /reference signal to be tracked and the values of d(t), d(t+1)……,d(t+h) are available for control where h represents the preview length which is a non negative integer. The control effort is the sum of the measured plant output and the previewed signal i.e.

$u(t) = kx(t) + \sum_{i=0}^{h} k_{di}(t+i)$ so as to minimize the following performance criterion:

$$J = \sum_{t=0}^{\infty} \left\| z(t) \right\|^2$$

The various advantages of preview control are:

- Improvement in steady state tracking.
- Improvement in low frequency tracking behavior.
- Reduction in control effort.
- Improvement in disturbance rejection.

This paper gives a brief journey of preview control. In the subsequent sections, examples, literature survey and conclusion of preview control has been represented.

Examples of Preview Control

Control system performance can be improved by utilizing the finite future information about the command signals and/or disturbances compared to the case when there is no idea about the future. Preview control has applications in the field of process control, reference tracking, motor control and robotics. To understand the concept of preview control the following two examples has been considered. Consider the task of driving a motorcycle along a curvy road. If the rider looks ahead for a short range then the handle can be steered late after the recognition of a curve which results in deviation from lane or an accident. For safe driving the rider tries to look ahead as far as possible and control the handle properly based on the future information of the lane. Similarly the road or traffic conditions can be previewed for better control. This means that the rider unknowingly using previewed reference signal to control his vehicle by treating lane as the reference signal and road or traffic conditions as disturbances.

As an industrial example, consider a continuous annealing process in which steel strips of accurate thickness, high tensile strength and high formability are produced by passing them through a heating, soaking, cooling and overaging furnace as shown in fig. 3. In this process the variations in entry thickness and temperature of the steel strip may act as disturbances which can affect the performance of the system. These disturbances can be previewed by an X ray gauge meter (for measurement of thickness) and a radiation pyrometer (for strip temperature measurement). Hence the system performance can be improved by making use of the above information.

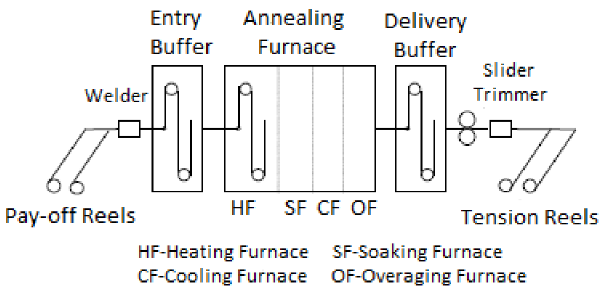

Fig.3. Outline of a continuous annealing process [13]

Literature Survey

Many researchers have worked and are still working in the field of preview control. T.B. Sherdan [2] discussed the response of an artificially intelligent controller which has a constrained preview of the actual input and the target values. The author discussed three models of preview control. The primary method is an extension of linear convolution in which the conventional impulse response or weighting function uses past as well as values to characterize constrained preview control but in this method for low order systems the shape of the weighting function cannot be obtained. The secondary method is a high speed dynamic model of the controlled process within the controller but the performance of this method is limited for future changes in target input function. The tertiary method involves optimization over the previewed course based upon preview information but this method can be applied for long previews where sudden expected changes do not occur in the system.

M. Tomizuka [3] formulated an optimal finite preview problem for continuous time systems. The author discussed the use of local future information obtained by finite preview to minimize the optimality criterion. It has been shown that critical preview length is helpful for improvement and reduction of tracking error for low frequency component of the command signal but this method suffers on the pretext that perfect measurement of the future command signal(s) is not feasible as preview information cannot be find out exactly.

Charles C. MacAdam [4] proposed an optimal preview control method for linear time invariant systems utilizing preview control strategies for regulation or tracking tasks. The proposed scheme is applied to the automobile path following problem, which can be viewed as a time lagged optimal preview control process. Due to preview signal the reduction in damping for the driver vehicle responses has been observed but in the proposed method the effect of the vehicle dynamics has not been considered in the transfer function of the system.

Donald A Pierre [5] proposed the design of look ahead or preview control systems using steady state error conditions relating to step and ramp inputs. The author concluded that there exists an optimum value of look ahead integer to improve the system performance but the time delays caused by finite calculation and time countered by preview control can affect the loop stability.

D.J Trudnowski and D.A Pierre [6] presented a performance limit for discrete time systems having finite settling time using preview control. The proposed approach has been derived for minimum phase case in single input single output systems (SISO) and has been designed to track step and ramp inputs with finite settling time. But the performance limit indicates that a tradeoff between step input response overshoot and settling time is required.

M.E. Harpern and MEngSc [7] discussed the design of optimal tracking systems using the polynomial based approach. The proposed approach has been used to solve a spectral factorization for the optimal closed loop poles followed by additional system zeros. The authors illustrated the above design procedure by taking example of aircraft terrain following system. The use of preview action reduces the pure delay between changes of terrain height and the aircraft response but the proposed design is applicable to deterministic case only. The system also assumes that actual values of reference signal are available which is not feasible.

M.E. Halpern [8] proposed the preview tracking problem with interpolation constraints restricting the set of admissible regulated outputs of a tracking system by incorporating preview control. In the proposed work l_1, l_2 and l_∞ norms have been minimized using preview control but by using this method the command generator structure becomes irrelevant for the design of linear quadratic (LQ) systems with infinite preview. Also more preview is required for plants with non minimum phase zeros near the stability boundary.

T. Hessburg and M. Tomizuka [9] designed a fuzzy logic controller (FLC) for controlling the lateral motion of a vehicle using feedback, preview and gain scheduling rule bases. Preview information regarding the upcoming radii of curvature has been taken into account for developing the rules of fuzzy logic controller. The advantage of FLC over a conventional controller is its ability to make use of variety of inputs but manual tuning the controller by trial and error is a tedious and time consuming task.

A. Matsushita and T. Tsuchiya [10] proposed a decoupled preview servo system design. When the weighting factors of the control input variables in quadratic performance index tends toward zero the optimal preview control system becomes a decoupled preview control system. The proposed method has been applied to the vector control system for an induction motor drive and is simple in comparison to trial and error method for the design of servo system. But very large control action is required for exact decoupling which is not practically feasible.

G. Prokop and R.S. Sharp [11] explained the use of preview information to reduce the order of a discrete time system. The proposed method has been applied to a quarter car system having limited bandwidth. The optimal control law is derived by using linear quadratic regulator (LQR) theory to discrete time system and the preview controller is implemented as a feed-forward gain matrix. The advantage of implementing preview control is the reduction in cost function upto a certain preview distance depending upon pass-band range of actuator but with short preview, performance in suspension working space and body acceleration cannot be improved.

E. Moska and A. Casavola [12] presented a solution to the linear quadratic tracking problem with previewed feed-forward action for discrete time invariant deterministic plants. The solution exhibits a separation property in which the two degree of freedom controller is made up by a feed-forward part which depends only on the future of the reference and feedback part which is equal to solution to the pure LQ regulation problem. The advantage is that the solution does not require a dynamic model of the reference.

A. Cohen and U. Shaked [13] proposed preview H_∞ tracking control for linear discrete time varying systems. The authors considered three parameters i.e. complete advance knowledge of reference signal, its online availability and the time interval for the preview control. Tracking problem is formulated as a game in which the controller plays against nature. A saddle point solution has been derived with necessary and sufficient conditions. The advantage of the proposed approach is that the dynamic model of the reference signal is not required but the problem is formulated for finite time case and not for infinite horizon, time invariant cases.

N. Yoshitani and A. Hasegawa [14] proposed a model based control of strip temperature for the heating furnace in continuous annealing process. The authors proposed a two level control in which the upper level is called optimal preview control for performing preset control that is taking actions well before a set up change and lower level is called temperature tracking control which performs closed loop control against sluggish, non minimum phase and slowly time varying characteristics of plant. The advantage of the proposed method is increase in production rate, energy conservation and quality improvement however the line speed at which the strip runs has not been chosen as a manipulated variable of temperature tracking control.

A. Kojima and S. Ishijima [15] discussed a generalized LQ control problem which covers a part of predictive control problem and clarify the strength and limitation of preview strategy in infinite horizon time setting. The optimal preview control has a structure of LQ feedback with preview compensation. In order to describe tracking error the disturbance is artificially introduced which would be a priori attenuated or the future information of the reference signal. Worst case initial uncertainties have been analyzed which minimize the cost functional of closed loop system and it is found that LQ preview control come to be similar to LQ control. The authors concluded that worst case analysis provides initial state uncertainties which cause definite damage to time domain performance.

C.E. Desouza and U Shakeed [16] proposed a robust filtering method for linear time varying systems against un-measurable stochastic noise inputs and measurable inputs. A linear filter has been designed with an input of bounded energy which has an error variance with a guaranteed upper bound. Both time varying finite horizon case and stationary infinite horizon case have been discussed. The advantage of the propose approach is better performance than robust kalman filtering and minimum variance filtering. But the preview knowledge in many cases is inaccurate or hardly available.

J. Chen, Z. Ren, S. Hara and L. Qiu [17] discussed tracking performance limitation problems. An exponentially increasing signal is considered as a reference signal instead of a step signal. It has been observed that the plant non minimum phase zeroes affects the tracking performance instead of the exponent of the reference input and the performance will be poor when the non minimum phase zeros are closely located. The authors also formulated the use of preview control for tracking. Exact solution or bounds has been derived for the optimal tracking error. The advantage of the proposed approach is reduction in tracking error while using preview especially in plant with non minimum phase zeros. But preview control increases the degradation of the system due to unstable poles.

J.I. Hernandez and C.Y. Kuo [18] presented a vehicle lateral control approach utilizing the advantage of both look down and look ahead reference systems. A preview based steering control algorithm based on road curvature preview using global positioning system (GPS) for achieving ride comfort and good road tracking has been proposed. The proposed algorithm is helpful in increasing ride comfort by lowering down the magnitudes of overshoots in vehicle's lateral acceleration and yaw rate.

Z.J. Wilozek, D. Philbrick, M.A. Kaya, A. Packard and G. Balas [19] proposed model predictive control strategy for a discrete non linear dynamic system where limited or finite preview information is available for the disturbances. The authors considered the problem as a dynamic game between control and disturbance. The proposed approach uses a suboptimal value function as a terminal cost and improvement is required rather than optimality in the optimization step. The advantage of the proposed approach is improvement in worst case performance over some nominal controller while maintaining the stability of closed loop system but the results are dependent upon consistent disturbance previews and not for unknown disturbance or noise in the framework.

H. Katoh [20] proposed H_∞ optimal preview control problem for continuous time systems. A method to design controller

has been derived which is based upon transfer function. The H_∞ optimal preview problem is reduced to a causal and finite dimensional H_∞ optimization problem whose solution is known. The limit of performance that is the relationship between preview horizon and H_∞ performance has been discussed by the author but H_∞ optimal preview problem with dead time has not been considered by the authors.

E. Gershon, D.J.N. Limebeer, U. Shaked and I. Yaesh [21] formulated finite horizon H_∞ tracking with preview for linear time varying systems in the presence of stochastic parameter uncertainties like white noise. The authors applied a game theory approach in which the controller plays against nature and a saddle point tracking strategy is obtained for finite horizon state feedback case which is based on the measurement of the system state and the previewed reference signal. The stochastic uncertainties leads to an error in estimating system state which depends on the past values of error as well as on the state multiplied by stochastic uncertainty but the authors have not discussed the output feedback tracking problem.

G. Tadmor and L. Mirkin [22] discussed continuous time H_∞ control and fixed lag smoothing problems for systems with preview. Necessary and sufficient characterization of suboptimal values has been derived using game theory approach in terms of H_2 and H_∞ algebraic riccati equations. The proposed solution has advantage that ill conditioned equations has not been considered and the resulting solution still exist when preview or smoothing lag increases but the result have been formulated in time invariant, infinite horizon setting.

G. Tadmor and L. Mirkin [23] discussed H_∞ preview tracking and fixed lag smoothing problems for discrete time linear systems. The authors presented preview information as a delay in the exogenous input for preview tracking problem and a delay between the measurement and the estimation generation in fixed lag smoothing problem. A complete solution to the preview H_∞ control and estimation problems based on fixed size algebra riccatti equations (AREs) has been presented by the authors.

M.M. Negm, J.M. Bakhashwain and M.H. Shwehdi [24] proposed speed control of a 3 phase induction motor based on optimal preview control system. The authors proposed control algorithms for speed control, field orientation control and constant flux control. A preview feed-forward controller has been proposed which includes the desired and the disturbance signals to improve the transient response of the system. By changing the rotor resistance and load torque the robustness of the proposed system has been verified by the authors.

G. Marro, D. Prattichizzo and E. Zattoni [25] proposed the problem of decoupling with preview. The authors formulated necessary and sufficient conditions for decoupling with finite preview in the geometric framework by exploiting the properties of minimal self bounded controlled invariant subspace satisfying the structural constraint. A compensator has been designed for the case where the stablizability condition is satisfied and where unstable unassignable internal eigen values of the minimal self bounded controlled invariant are present but if the stablizability condition does not holds it is not possible to achieve decoupling of the external input with internal stability.

A. Kojima and S. Ishijima [26] discussed H_∞ preview control problem with delayed control strategies using state space approach. The analytic solution to the algebraic riccatti equation has been established by introducing a Hamiltonian matrix defined with a delay free system. The authors formulated the H_∞ control problem based upon the new results and some interpretations have been provided on the property of the resulting control system. But as the uncertainty in the information increases the effect of preview strategy decreases hence H_∞ performance depends on the trade-off between the strength of preview action and limitation of delayed action.

L. Mianzo and H. Peng [27] proposed a closed loop control scheme for an electromagnetic valve actuator based on preview control that achieves robust and reliable operation in the presence of significant delays in an electromagnetic system associated with eddy current losses. The information regarding desired trajectory of the armature position is known in advance. The advantage of preview control is improvement in tracking performance and disturbance rejection but preview control affects the noise level due to engine operation.

K.Y. Polyakov, E.N. Rosenwasser and B.P. Lampe [28] formulated optimal preview control problem for stochastic single input single output sampled data systems. The authors proposed a frequency domain solution of the problem for SISO sampled data systems based on parametric transfer function approach in which the numerator and denominator degrees of the optimal controller has been calculated. It has been observed that as the preview length tends towards infinity the optimal cost function approaches towards the periodic function of preview length. But with the increase in preview length, stabilization and tracking performance become contradictory.

L. Mirkin and G. Tadmor [29] proposed solution of the fixed lag smoothing problem as a constrained version of the fixed interval smoothing problem. The finite preview of the fixed lag problem has been treated as an added analyticity constraint on gain. The proposed approach leads to a partition of the factors determining smoother performance. The authors formulated the dependence of achievable performance on the preview length and on the generic presence of performance saturation at a finite preview interval.

E. Zattoni [30] proposed the solution of discrete time finite horizon optimal control problems. The optimal value of the cost functional, the optimal control sequences and the optimal state trajectories have been derived through the characterization of a pair of structural invariant subspaces obtained by solving a discrete algebraic Riccatti equation and a symmetric stein equation of the associated singular Hamiltonian system. The proposed methodology has the application in H_2 optimal rejection of signals known with a finite preview but the numerical implementation of the suggested approach is quite complex.

K.D. Running and N.C. Martin [31] proposed the solution to the infinite horizon optimal preview control problem for a plant that is linear but varies in time according to a Markovian process in the presence of infinite preview. The optimal control policy consists of a feed-forward and a feedback control. The authors have shown that the feedback part is identical to the standard optimal linear quadratic regulator for Markovian jump linear systems and the convergence of the feed-forward term follows immediately from the stability of the closed loop state space representation but this convergence result cannot be extended to Markovian jump linear systems.

B. Asad and A. Vhidi [32] proposed the use of upcoming traffic signal information within the vehicle's adaptive cruise control system to reduce idle time at traffic signals and fuel consumption. The authors formulated an optimization based control algorithm based on preview control which uses short range radar and traffic signal information to obtain an optimum velocity trajectory for the vehicle but proposed methodology depends on timing and phasing of traffic lights. Distance between the traffic lights and the vehicle parameters also effect the performance of the system.

A.T. Salon, Z. Chen, J. Zheng and M. Fu [33] proposed a preview control design method for reducing the settling time of dual stage actuators. The authors proposed a control strategy which uses the future information regarding the reference levels of the actuator in order to compute a pair of inputs to be applied before the output transition time. The advantage of the proposed method is reduction in the output transition time but the authors assumed the availability of true states, however, practically the availability of true states is not feasible.

T.K. Dao and C.K. Chen [34] proposed a path tracking controller with path preview for a motorcycle. With the help of system identification technique the non linear motorcycle model has been converted into a linear model and full state feedback is designed for roll angle tracking control. The advantage of the proposed controller is robustness against changes in speed as well as external disturbances.

Conclusion

Preview length plays a vital role in improving system performance. The required preview length is entirely dependent on the position of the continuous non minimum phase zeroes. Hence, an optimal value of preview length is necessary to achieve desired control.

Preview control task involve a time delay. A time delay may lead to a system with very higher order which will make the controllers computationally complex and difficult to implement. Also noisy preview signals may require a higher order controller. But the preview control helps to reduce the error by improving the control effort and disturbance rejection.

REFERENCES

[1] K. Takaba, A tutorial on preview control systems, *SICE Annual Conference in Fukui Japan,* August 2003, pp. 1561-1566

[2] Thomas B. Sheridan, Three models of preview control, *IEEE Transactions on Human Factors in Electronics*, *vol. HFE-7 n. 2,* June 1966, pp. 91-102.

[3] M. Tomizuka, Optimal continous finite preview problem, *IEEE Transactions On Automatic Control*, *vol. AC-20,* June-1975, pp. 362-365.

[4] C.C. MacAdam, Application of an optimal preview control for simulation of closed loop automobile driving, *IEEE Transactions On Systems, Man and Cybernetics, vol. SMC-11 n. 6*, June 1981, pp. 393-399.

[5] D.A. Pierre, Steady state error conditions for use in the design of look ahead digital control systems, *IEEE Transactions On Automatic Control, vol. AC-27 n. 4*, August 1982, pp. 943-945.

[6] D.J. Trundnowski, D.A. Pierre, A performance limit for a finite settling time system using look ahead control, *IEEE Transactions On Automatic Control, vol. 34 n. 7*, July 1989, pp. 760-763.

[7] M.E. Halpern, MengSc, Optimal tracking with previewed commands, *IEE Proceedings-D, vol. 138 n. 3*, May 1991, pp. 237-241.

[8] M.E. Halpern, Preview tracking for discrete time SISO systems, *IEEE Transactions On Automatic Control, vol. 39 n. 3*, March 1994, pp. 589-592.
[9] T. Hessburg, M. Tomizuka, Fuzzy logic control for lateral vehicle guidance, *IEEE Control Systems*, August 1994, pp. 55-63.
[10] A. Matsushita, Decoupled preview control system and its application to induction motor, *IEEE Transactions On Industrial Electronics, vol.42 n. 1*, February 1995, pp. 50-57.
[11] G. Prokop, R.S. Sharp, Performance enhancement of limited bandwidth active automotive suspensions by road preview, *IEE Proceedings On Control Theory Applications, vol.142, n. 2*, March 1995, pp. 140-148.
[12] E. Mosca, A. Casavola, Deterministic LQ preview tracking design, *IEEE Transactions On Automatic Control, vol. 40 n. 7*, July 1995, pp. 1278-1281.
[13] A. Cohen, U. Shaked, Linear discrete time H_∞ optimal tracking with preview, *IEEE Transactions On Automatic Control, vol. 42 n. 2,* February 1997, pp. 270-276.
[14] N. Yoshitani, A. Hasegawa, Model based control of strip temperature for the heating furnace in continous annealing, *IEEE Transactions On Control Systems Technology, vol. 6 n. 2*, March1998, pp. 146-156.
[15] A. Kojima, S. Ishijima, LQ preview synthesis: Optimal control and worst case analysis, *IEEE Transactions On Automatic Control, vol. 44 n. 2*, February 1999, pp. 352-357.
[16] C.E. de Souza, U. Shaked, Robust H_2 filtering for uncertain systems with measurable inputs, *IEEE Transactions On Signal Processing, vol. 47 n. 8*, August 1999, pp. 2286-2292.
[17] J. Chen, Z. Ren, S. Hara, L. Qiu, Optimal tracking performance: Preview control and exponential signals, *IEEE Transactions On Automatic Control, vol. 46 n. 10*, October 2001, pp. 1647-1653.
[18] J.I. Hernandez, C.Y. Kuo, Steering control of automated vehicles using absolute positioning GPS and magnetic markers*, IEEE Transactions On Vehicular Technology, vol. 52 n. 1*, January 2003, pp. 150-161.
[19] Z.J. Wloszek, D. Philbrick, M.A. Kaya, A. Packard, G. Balas, Control with distance preview and online optimization, *IEEE Transactions On Automatic Control, vol. 49 n. 2,* February 2004, pp. 266-270.
[20] H. Katoh, H_∞ optimal preview controller and its performance limit, *IEEE Transactions On Automatic Control, vol. 49 n. 11,* November 2004, pp. 2011-2017.
[21] E. Gershon, D.J.N. Limebeer, U. Shaked, I. Yaesh, Stochastic H_∞ tracking with preview for State multiplicative systems, *IEEE Transactions On Automatic Control, vol. 49 n. 11,* November 2004, pp. 2061-2068.
[22] G. Tadmor, L. Mirkin, H_∞ control and estimation with preview-Part I: Matrix ARE solutions in continous time, *IEEE Transactions On Automatic Control, vol. 50 n. 1*, January 2005, pp. 19-28.
[23] G. Tadmor, L. Mirkin, H_∞ control and estimation with preview-Part II: Fixed size ARE solutions in discrete time, *IEEE Transactions On Automatic Control, vol. 50 n. 1*, January 2005, pp. 29-40.
[24] M. M. M. Negm, J.M. Bakhashwain, M.H. Shwehdi, Speed control of a three phase Induction motor based on robust optimal preview control theory, *IEEE Transactions On Energy Conversion, vol. 21 n. 1*, March2006, pp. 77-84.
[25] G. Marro, D. Prattichizzo, E. Zattoni, A unified setting for decoupling with preview and Fixed- lag smoothing in the geometric context, *IEEE Transactions On Automatic Control, vol. 51 n. 5*, May2006, pp. 809-813.
[26] A. Kojima, S. Ishijima, Formulas on preview and delayed H^∞ control, *IEEE Transactions On Automatic Control, vol. 51 n. 12*, December 2006, pp. 1920-1937.
[27] L. Mianzo, H. Peng, Output feedback H_∞ preview control of an electromechanical valve Actuator, *IEEE Transactions On Control System Technology, vol.15 n. 3*, May 2007 pp. 428-437.
[28] K.Y. Polyakov, E.N. Rosenwasser, B.P. Lampe, Optical stochastic SD control with preview, *IEEE Transactions On Automatic Control, vol. 52 n. 8*, August 2007, pp. 1532-1538.
[29] L. Mirkin, G. Tadmor, On geometric and analytic constraints in the H_∞ fixed-lag smoothing, *IEEE Transactions On Automatic Control, vol. 52 n. 8*, August 2007, pp. 1514-1519.
[30] E. Zattoni, Structural invariant subspaces of singular hamiltonian systems and non-recursive Solutions of finite-horizon optimal control problems, *IEEE Transactions On Automatic Control, vol. 53 n. 5*, June 2008, pp. 1279-1284.
[31] K.D. Running, N.C. Martins, Optimal preview control of markovian jump linear systems, *IEEE Transactions On Automatic Control, vol. 54 n. 9*, September 2009, pp. 2260-2266.
[32] B.A. Asadi, A. Vahidi, Predictive cruise control: Utilizing upcoming traffic signal information for improving fuel economy and reducing trip time, *IEEE Transactions On Control Systems Technology, vol. 19 n. 3*, May 2011, pp. 707-714.
[33] A.T. Salton, Z. Chen, J. Zheng, M. Fu, Preview control of dual stage actuator systems fo rSuperfast transition time, *IEEE Transactions On Mechatronics, vol. 16 n. 4*, August2011, pp. 758-763.
[34] T.K. Dao, C.K. Chen, Path tracking control of a motorcycle based on system identification, *IEEE Transactions On Vehicular Technology, vol. 60 n. 7*, September 2011, pp. 2927-2935.

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